Scoates' Agricultural Surveying Laboratory Manual

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INDEX

INTRODUCTION

This Manual is primarily written for agricultural students attending agricultural colleges. The principal thing kept in mind in selecting, compiling and arranging the Exercises, was to stress only those things which are necessary to a thorough understanding of surveying needs as are found on the average farm.

The Manual is divided into four parts: (1). The part giving the assignments for the different work to be done. (2). Sample pages showing how the laboratory work should be written up. (3). Blank pages on which the student is to write up his work. (4). Tables of information useful to the student in this laboratory work.

Each student should have a Manual, and as soon as he gets it he should write his name in ink on it, thus insuring its return in case of loss.

Make a practice of writing up each day's notes in a complete form the day they are taken. This will prevent the complete loss of a record of the day's work if one of the party should lose his book.

Don't fudge your notes. This is only stealing from yourself. While it may get you past the instructor, yet it does not give you the practice you are taking this course to receive. It is better not to make any erasures in your note book, but rather to cross out the mistake, thus avoiding the appearance of fudging. All notes should be neatly lettered and not written.

The note book should be handed in to the instructor for inspection on the following dates:.....

.....

PARTIES

The classes shall divide themselves up in parties of three each. Each party shall elect a captain who shall turn in the names of his party to the instructor. The captain shall represent his party in getting assignments for the day's work. In selecting the members to constitute the various parties, several things should be kept in mind. Get in the same party men who will work well together, are punctual and want to work with the same degree of speed; place in the same party all the loafers, and men who are habitually late; place together in the same party all the athletes, as they usually leave early. If this is followed out, much of the discontent can be eliminated from the course, as in very few of the exercises can one or two men work alone.

ABSENCES.

When students are absent from the laboratory work, they will not be given credit for the work done by their party that day. There is just so much laboratory work to be done and when the student finishes that amount, he is done. Each student will be required to do the alloted amount.

CARE OF SURVEYING EQUIPMENT.

Each party will be provided with a key to a steel locker in the laboratory. A deposit of twenty-five cents will be required to insure the return of the key. In this locker will be found the following articles: Level, level rod, 100 foot tape, plumb bob, 11 pins, 2 range poles, and a hatchet. Each party will be held responsible for the equipment in their locker. As two or more parties use the same locker, each party must return all the equipment to the

locker each night. Any party may use the equipment on days that other parties are not assigned to use it.

The level is a delicate instrument and should be handled with extreme care. **Should you drop or in any way damage it, bring it immediately to the instructor.** Should you try to use it after having damaged it, the results you obtain will be more than apt not to check. **Under no condition take the instrument apart,** as there are parts easily ruined by a slight breeze. Never set the instrument upon a concrete floor and leave it, as the legs are liable to slip thus allowing the instrument to fall. Never go away and leave the level setting up in a field where there is stock as the stock are liable to damage it. In case of rain shield the level proper, either by placing it under your coat or some other way of providing cover for it.

The level rod depends for its value on the painted lines and figures on its surface. Care should be exercised to prevent these becoming scratched or in any way damaged. Do not throw the rod on the ground or do anything to scar its face.

The range poles are fragile and if care is not taken of them they are liable to become broken. Their serviceability depends on the condition of their paint, so see that they are not unduly used. Do not attempt to spear chickens or vault ditches with them.

The plumb bob should have its string coiled up each time it is put away and do not damage the point of the bob.

The steel tape can be easily broken. Be careful in undoing it to see that no kinks are allowed to go unnoticed, as they will result in a broken tape. Do not allow teams or trains to run over them. After using the tape, it should be properly done up and tied securely.

The hatchet and pins need to receive proper attention in order to be ready for another day.

INVESTIGATING PACE

Exercise 1

Equipment.—Note book.

Assignment.—Investigate length of pace: (a) Natural step. (b) Assumed three foot step.

Instructions.—(a) Walk over the assigned course of 300 feet ten times, five times each way, walking as you naturally do. (b) Walk over the same course the same number of times, walking with an assumed step that you always thought was about three feet.

Record all results in note book and compute average length of natural step and assumed step. Throw out all values that vary more than two per cent.

Specimen pages showing how notes should be written up will be found on pages 26 and 27.

CHAINING DISTANCES

Exercise 2

Equipment.—100 foot tape, set of pins, two range poles and plumb bob.

Assignment.—Chain distance both ways between the two or more points assigned by the instructor. Recording distance to the nearest .01 feet.

Instructions.—Set the range poles at the points to be chained between. Head chainman takes all the pins, giving the rear chainman one pin. Rear chainman should always line head chainman in. Between stations, rear chainman should drop chain and let it drag on the ground. Going up and down hills, be sure to use the plumb bob. Head chainman going one way, will be rear chainman returning.

Record work neatly in note book.

Two chainings should not differ more than one foot in 5,000 feet.

Specimen pages showing how notes should be written will be found on pages 28 and 29.

DETERMINING ANGLES WITH TAPE

Exercise 3

Equipment.—100 foot tape, set of pins and 2 range poles.

Assignment.—Determine the three angles in the triangle assigned by the instructor, using both methods on each angle (a). Sine Method; (b). Tangent Method.

Instructions.—(a) Sine Method. Set range poles on the boundary lines of the angle to be measured. Measure from the vertex of the angle and along both boundary lines any number of feet, say 50 or 60. Be sure to measure the same number of feet on each boundary line. Place a pin at each of these points. Measure distances between these points to the nearest .01 of a foot. Half this distance divided by the distance measured out on the boundary line from the vertex of the angle will give the natural sine of half the angle.

(b) Tangent Method.—Proceed as in (a) Sine Method. When distance between the two pins on boundary lines is obtained, locate half way point between these pins and then measure distance between this half-way point and vertex of angle. This last distance divided into half the distance between the two points on boundary lines will give natural tangent of half the angle.

Record all work in note book.

Specimen pages showing how notes should be written will be found on pages 30 and 31.

COMPUTING AREA OF TRIANGLE

Exercise 4

Equipment.—100 foot tape, two range poles and set of pins.

Assignment.—Determine the area of the triangle by three different methods: (a) Three-side method, (b) Angle method, (c) Perpendicular method.

Instructions.—Use same triangle assigned in Exercise 3. (a) Three-side method: Measure sides of triangle. Compute the area in square feet and in acres by use of the following formula:

Area equals $\sqrt{s\,(s-a)\,(s-b)\,(s-c)}$,

a plus b plus c, equal 2S;

a, b and c represent lengths of sides of triangle.

(b) Angle method: Using angle values obtained in Exercise 3, compute area in square feet and in acres by use of the following formula:

Area equals: One-half the product of two sides times the sine of the included angle.

(c) Perpendicular method: Drop a line from the vertex of an angle through the base opposite the angle; having line perpendicular to base. Measure length of this line. Compute area in square feet and in acres by use of the following formula:

Area equals: ½ base times altitude.

Record in your note book.

Specimen pages showing how notes should be written up will be found on pages 32 and 33.

LAYING OUT BUILDING

Exercise 5

Equipment.—100 foot tape, two range poles, set of pins and hatchet.

Assignment.—Lay out building on a flat field, of the size and shape given by instructor, using 100 foot steel tape.

Instructions.—Direction of one side and location of one corner, together with diagram of building, will be obtained from instructor. Measure length of one side and erect at corners of this side perpendiculars by using the 3, 4, 5 method. Measure length of these sides and set pins. You now have the four corners. Check by measuring diagonals; they should be equal. Any additional parts of the building can now be added in the same manner. Set stakes at the corners.

When the entire building is staked out, call the instructor for approval.

Record in your note book.

Specimen pages showing how notes should be written will be found on pages 34 and 35.

DIFFERENTIAL LEVELING

Exercise 6

Equipment.—Level, level rod and hatchet.

Assignment.—Determine the difference in elevation between the two points assigned by the instructor.

Instructions.—The elevation of one of the points will be given by the instructor. Starting at that point, run a line of differential level over to the other assigned point, and when that point is reached, move the instrument, making a new set up and

using the elevation obtained run another line of differentials back to the original starting point.

Pay particular attention to the following points:

Don't take too long sights.

Always hold the rod on a stake, concrete walk, railroad rail or some other substantial point.

Have each man in party read rod in order to get practice and as a check.

Assign each man in the party a definite job.

The difference between the elevations taken at the start and that obtained after making the circuit should not be greater than .007 times the square root of the number of hundred feet the circuit includes.

Record all readings in note book as fast as they are made.

Specimen pages showing how notes should be written will be found on pages 36 and 37.

PROFILE LEVELING

Exercise 7

Equipment.—Level, level rod, hatchet and 100 foot tape.

Assignment.—Stake out, run profile levels and make profile for tile drain along line assigned by instructor.

Instructions.—Starting at the outlet, place two stakes every 50 feet, 1½ feet off line where tile is to be laid. One of these stakes is to be put down flush with the ground; the other is to show about one foot above the ground. Number stake at the outlet 0–|–0, the next one 0–|–50, then 1–|–0, etc.

Start at the B. M. and run a line of differential levels to one end or the other of the profile line, then take readings on top of profile stakes that are

driven flush with top of ground. When the elevation of the last station is obtained, run a line of differential levels back to the B. M. for a check.

Plot up profile on standard Plate B profile paper.

Locate a line of title on the profile, and determine cut at each station.

Record all notes in note book.

Specimen pages showing how notes should be written up will be found on pages 38 and 39.

READING ANGLES WITH INSTRUMENTS

Exercise 8

Equipment.—Level, plumb bob and two range poles.

Assignment.—Using architect's level, determine the size of each of three angles in the triangle assigned by the instructor.

Instructions.—Place range poles on boundary lines of angle to be measured. Set the instrument up over the vertex of the angle, level instrument and sight on one range pole, get graduated circle to read zero. Sight on the other range pole and read angle.

Instructor will give detail instructions as to how to read angles on graduated circles.

Repeat for each angle.

Record results in note book.

Specimen pages showing how notes should be written up will be found on pages 40 and 41.

TOPOGRAPHICAL SURVEYING

Exercise No. 9

Equipment.—Level, level rod, range poles, hatchet and 100 foot steel tape.

Assignment.—Make a topographical survey of plot assigned by instructor.

Instructions.—Measure length of sides and size of all angles. Divide the plot in 100 foot squares, placing a stake at each corner of the squares. Put station numbers on all stakes. Run line of differential levels from bench mark to plot and establish temporary bench mark. Take the elevation of the ground at each stake to the nearest .1 foot.

Locate all roads, fences, buildings and ditches.

Make map of the plot, using a scale of one inch or decimal of an inch equals 100 feet, the scale being of such size to get a map that will conveniently fill a sheet of 18x24 drawing paper. Place contours on the map for every foot difference in elevation unless land is too rolling, then use two foot or five foot intervals. Plot in all roads, buildings, fences and ditches.

Contour lines should be inked in as well as other things noted above. Elevations of points obtained should be noted with pencil on map.

Record all notes taken in note book, using same form as used in profile leveling.

DESIGNING DRAINAGE SYSTEMS

Exercise 10

Equipment.—Same as Exercise 9.

Assignment.—Design the drainage system for the plot used in Exercise 9.

Instructions.—Using map made in Exercise 9,

design system of tile drainage, placing tile 80 feet apart and 30 inches deep. These lines of tile should be plotted on the map and inked in. When system is designed, take map to the instructor and he will select two lines of tile thereon. Stake these two lines out on the field and run profile levels over each. Plot up the profile, also the tile underneath it, having it at proper depth. Figure cuts for each station.

Put length of tile lines and size of tile to be used on map. Make out bill of materials needed and give estimate of cost.

Record all notes in note book.

TILE INTERSECTION

Exercise 11

Equipment.—Tile spades, shovels, guage rod, string, ditch cleaner, hatchet and nails.

Assignment.—Put in an intersection of a lateral and main tile drain.

Instructions.—Using same two lines of tile that were staked out in Exercise 10. At intersection of two lines, put up string and dig ditch, smooth bottom and place four feet of tile on each line in the same as you would do in actual work.

Call attention of the instructor when the work is done.

TERRACING

Exercise 12

Equipment.—Home-made level, hatchet, farm level and rod.

Assignment.—Using both methods, locate ter-

races on the plot assigned by the instructor: (a) Using home-made level; (b) Using farm level.

Instructions.—(a) Locate two terraces on assigned hillside, using home-made level. Keep track of time it takes to run out terrace, together with length of terrace. (b) Locate two more terraces on the assigned hillside, using farm level. Keep track of time and length of terrace.

In both cases, give terrace fall of six inches per hundred feet, and distance between terrace to be difference in elevation of six feet.

Record data.

LAYING OUT BUILDING

Exercise 13

Equipment.—Level, level rod, hatchet, 100 foot tape, pins and nails.

Assignment.—Using architect's level, lay out foundation and put up batter boards for building assigned by instructor.

Instructions.—Instructor will furnish party with blue print of building to be used, assign a place to put the building and designate direction of one side and location of one corner.

Lay off angles at corner of building with architect's level, measure sides with tape. Set stake with nail in top of it at each corner. Place batter boards two feet outside on each side of corner. Have top of boards level all around and at height of foundation. Place a nail in each board on line with side of buildings.

Check diagonals of buildings.

Record all in note book and draw diagram of building.

ADJUSTMENT OF LEVEL

Exercise 14

Equipment.—Level, level rod and hatchet.

Assignment.—Determine whether the level is out of adjustment. If it is, adjust it.

Instructions.—Following the method outlined below in adjusting level.

Record all work done in note book.

In making the adjustment on any of the surveying instruments, first determine if it needs adjustment. If it does not, do not tamper with the instrument just for the sake of seeing how it is made. Many a good instrument or machine is often spoiled or thrown out of repair by its owner or user not being able to leave well enough alone. When an instrument needs adjustment, go about making it with extreme care and caution. Surveying instruments are necessarily very delicate and should be so treated. In the wooden case that the instrument is kept, will be found the necessary pins, etc., to be used in adjusting the instrument. Use them with care and do not use large amounts of force, as all adjusting screws should and will move easily when properly adjusted. **Under no condition take the instrument apart.**

ADJUSTMENT OF WYE LEVEL

The adjustment of the Wye level consists of four distinct adjustments. These should be taken up in the order that they are given.

Adjustment of Cross Hairs.—This consists of getting the horizontal cross hairs horizontal and line of sight to coincide with centers of the pivot rings.

To get the horizontal cross hair in a horizontol position, first level up the instrument and sight on some distant point, such as a pencil point on a brick wall. This point should rest on the horizontal

cross hair. Next move the telescope so that it rotates around its vertical axis, the point should appear to move along the horizontal cross hair and traverse its entire length. If it does this, the cross hair is in adjustment, if it does not, the small capstan screws that hold the cross hairs should be loosened and the cross revolved until the above condition is satisfied, then the screws tightened. If there are more than one horizontal cross hair in the instrument, work with the middle one.

To get the line of sight to coincide with the centers of the pivot rings, have the instrument level as before and sight on some distant point that comes on the intersection of the two cross hairs. Then unclamp the telescope in the wyes and revolve the telescope 180° or so the bubble tube is above the telescope. If the intersection of the cross hairs remains on the point during this operation, the line of sight coincides with the center of the pivot rings. If it does not, then adjust the cross hairs by means of the capstan screws half the apparent error. Repeat until correct. The horizontal cross hair can be moved up by loosening the lower capstan screw and tightening on the upper; it can be moved down by reversing the operation. The vertical cross hairs can be moved to the right or left by loosening the screw on the opposite side towards which it is to be moved, tightening on the other side.

To Adjust the Axis of the Bubble Tube Parrallel to the Line of Sight.—There are two methods of doing this, the indirect and direct. While the indirect is quicker, it is not so accurate, and the direct or peg method will be given here.

The peg adjustment is made by driving two stakes in the ground about 150 feet apart. Set the instrument up in front of one of these stakes so that when it is leveled up and a rod held on the stake, it will come within one-half or one-fourth inch of the end of the telescope. Make a reading on

the rod at this point by turning the eye end of the telescope toward the rod and looking in the wrong end of the telescope. Place the point of a pencil on the rod to help in reading it. The center of the field of view is the place to put the point of the pencil, and the rod should be read at this point. (Fig. 1.) Let this instrument be set up at A,

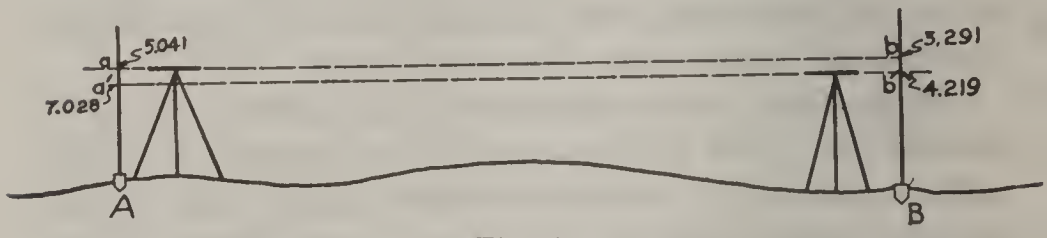

Fig. 1.

and this first rod reading be a. There sight on the rod held on B, this rod reading being b. Next move the instrument to the station B and make a reading on B which is called b′. Likewise a reading is made on A and is called a′. Now, if the instrument is in adjustment, the difference between a and b will equal the difference between a′ and b′, because these differences represent the difference in elevation between the two stakes A. and B. However, if the differences are not equal, then the true difference in elevation will be equal to mean of the two differences. This can be obtained by adding the two differences together and dividing by two. Then determine by use of this true difference what the rod reading should be on A. (The instrument still being at B.) This can be done by determining the difference between the a′ and b′ difference and the true difference and adding or subtracting to it the rod reading on a or a′, in order to make the rod such an amount as to make the difference between it and b′ equal to the true difference. Set the target on the rod to read this amount and bring the horizontal cross hair to read on the target by means of the leveling screws. Then bring the bubble to the cen-

ter of the tube by means of the bubble adjustment screws at the end of the bubble.

Repeat the entire operation until the level shows that it is in perfect adjustment.

Example

Instrument at A.

Rod reading on A-a . . .	5.041
Reading on B-b	3.291
Difference	1.750

Instrument at B.

Reading on B-b′	4.219
Reading on A-a′	7.029
Difference	2.810

Mean difference equals 1.750 plus 2.810 divided by 2, equals 2.280. The difference between 2.810 and 2.280 is .530. The rod when held on A (the instrument still at B) should read 6.499—(7.029 minus .530)—in order to have the correct differences, because the difference between b′ and a′ is greater than the true difference.

Adjust the Axis of the Bubble Tube in the Same Plane With the Line of Sight.—Level the instrument, then clamp the telescope in the wyes and rotate the telescope in the wyes a very little; if the bubble remains in the center of the tube, it is in adjustment. If it moves toward one end, then adjust by the azimuth screws, the ones that control the lateral movements of the bubble tube. Repeat until correct.

To Adjust the Axis of the Bubble Tube Perpendicular to the Vertical Axis of the Instrument.—This adjustment is not absolutely necessary in order

to get the correct readings, but is made as a matter of convenience, as it insures that the instrument can be leveled so when turned in any direction, it will remain level. To determine whether the level needs adjustment, first level it up over two screws and then over the other two, repeat two or three times. Then turn it through 180°; if it remains level, it is in adjustment. If, however, when turned the bubble moves toward one end or the other, it is out of adjustment. Proceed to correct half of the distance the bubble is out by means of the leveling screws, and the other half should be corrected by adjusting screws on the bottom of the wye. Repeat until in adjustment.

Adjusting Dumpy Level.—The method used in adjusting a dumpy level is somewhat similar to the wye level, but the adjustments are taken up differently and made at different points. Care should be taken to take its adjustments up in the order given. There are three adjustments to be made.

Adjustment of Cross Hairs.—The horizontal cross hair should be horizontal, and the method used in determining its adjustment and making same is similar to the wye level which is given above.

To Adjust the Axis of the Bubble Tube Perpendicular to the Vertical Axis of the Instrument.—The testing of the instrument to determine its adjustment is the same as given for the wye level. To make the adjustment, half the correction is made with the leveling screws, the same as for the wye level, but the other half is made by the raising or lowering one end of the bubble tube instead of the wye, as on the wye level.

To Adjust the Line of Sight Parallel to the Axis of the Bubble Tube.—The determining of the condition of the level is the same as given for wye level. If out of adjustment, the proper reading is deter-

mined as before given, but instead of bringing the instrument to read this reading by means of the leveling screws, the cross hairs are moved up or down until they read the proper place and the leveling screws are not touched.

SPECIMEN LABORATORY NOTES

Kind of Pace	Paces	Total	Average	Length
Natural				
1	112.0			
2	113.0			
3	112.5			
4	112.0			
5	112.7			
6	111.5			
7	112.5			
8	113.0			
9	112.0			
10	113.3	1123.5	112.35	2.66
Assumed				
1	102.00			
2	101.00			
3	103.00			
4	101.25			
5	101.00			
6	101.25			
7	101.00			
8	102.00			
9	101.25			
10	101.00	1014.75	101.48	2.96

INVESTIGATING PACE

Exercise 1

January 12, 1913.

Paul P. Jones.

Length of Course . . . . . 300 feet.

Line	Dir.	Length	Diff.	Ratio
A to B	East	3000.0		
B to A	West	3000.5	0.5	1:6000

CHAINING DISTANCES

Exercise 2

January 15, 1913.

Party.

Paul P. Jones, Chainman.
Sam S. Smith, Chainman.
Roy R. West, Recorder.

Point "A" was the southeast corner of the lower step at front of Agricultural Hall. Point "B" was the northeast corner of the lower step at front of Textile Building.

SINE METHOD

Angle	Hypo.	½ Dist.	Sine ½ Angle	½ Ang.	Angle
ABC	50	26.25	.5250	31° 40′	63° 20′
BCA	50	25.94	.5188	31° 15′	62° 30′
CAB	50	22.81	.4562	27° 8′	54° 16′
				Total,	179° 76′

TANGENT METHOD

Angle	Base	½ Dist.	Tan. ½ Angle	½ Ang.	Angle
ABC	42.61	26.25	.6165	31° 39′	63° 18′
BCA	42.80	25.94	.6060	31° 13′	62° 26′
CAB	44.50	22.81	.5126	27° 8′	54° 16′
				Total,	180° 00′

DETERMINING ANGLES WITH TAPE

Exercise 3

January 16, 1913.

Party.

Paul P. Jones, Chainman.
Roy R. West, Chainman.
Sam S. Smith, Recorder.

(Draw a diagram of the triangle you worked on, giving the letters you used.)

THREE SIDE METHOD

Side	Dist.	Area Sq. ft.	Area Acres
a	220.3		
b	101.5		
c	270.75		
S	296.275		
S-a	75.975		
S-c	25.525		
S-b	194.775	10578.6	.243

ANGLE METHOD

Side	Dist.	Area Sq. ft.	Area Acres.
a	220.3		
b	101.5		
Sin C.	.9463	10579.8	.243

PERPENDICULAR METHOD

Side	Dist.	Area Sq. ft.	Area Acres
c	270.75		
Perp.	78.2	10586.3	.243

COMPUTING AREA OF TRIANGLE

Exercise 4

January 17, 1913.

Party.
Roy R. West Chainman.
Sam S. Smith, Chainman.
Paul P. Jones, Recorder.

(Draw a diagram of the triangle you worked on, giving the letters used.)

Line	Length
A-B	200.
A-C	52.
C-F	25.
D-E	125.
F-G	10.
G-H	50.
A-Z	209.2
B-Y	209.3
F-H	50.98
E-G	50.95

LAYING OUT BUILDING

Exercise 5

January 18, 1913.

Party.
Paul P. Jones, Chainman.
Sam S. Smith, Chainman.
Roy R. West, Recorder.

(Draw a diagram of the building you worked on; giving the letters you used.)

Sta.	-|- S	H. I.	— S	Elev.
B. M.				100.00
	4.82			
1		104.82	6.81	98.01
	3.38			
2		101.39	8.51	92.88
	3.445			
3		96.325	4.96	91.365
	10.36			
4		101.725	0.348	101.377
	9.36			
5		110.737	0.59	110.147
	0.585			
6		110.732	9.24	101.492
	0.495			
7		101.987	10.29	91.697
	4.71			
8		96.407	3.425	92.982
	8.525			
9		101.507	4.43	97.077
	7.77			
10		104.847	4.84	100.007
Check	53.450		53.443	
	53.443			100.007
	.007			100.000
				.007

DIFFERENTIAL LEVELING

Exercise 6

January 20, 1913.

Party.

Paul P. Jones, Levelman.
Roy R. West, Rodman.
Sam S. Smith, Recorder.

B. M. is a cross on the southeast corner of the lower stone step in front of Agricultural Hall. Station 5 was the northwest corner of lower stone step in front of Textile Building.

Sta.	–|– S.	H. I.	— S	Elev.	G. L.
B. M.				100	
	1.70	101.70			
0 –|– 0			5.43	96.27	89.40
0–|–50			7.96	93.74	91.20
1 –|– 0			6.30	95.40	92.80
1–|–50			4.46	97.24	94.40
2 –|– 0			3.25	98.44	96.00
2–|–50			1.63	100.07	97.50
2–|–86			1.70	100.00	98.00
	3.40	103.40			
B. M.			3.39	100.01	

PROFILE LEVELING

Exercise 7

January 21, 1913.

Cut.

6.87

2.54

2.60

2.80

2.44

2.57

2.00

Party.

Sam S. Smith, Levelman.
Roy R. West, Rodman.
Paul P. Jones, Recorder.

B. M.—Nail on south side of hickory tree, ten feet north of foot bridge.

Angle.	Degrees.	Min.
ABC	61	32
BCA	90	51
CAB	27	40
Total	180	3

READING ANGLES WITH INSTRUMENT

Exercise 8

January 22, 1913.

Party.
Paul P. Jones, Instrumentman.
Roy R. West, Rodman.
Sam S. Smith, Rodman.

(Draw a diagram of the triangle you worked on giving the letters used.)

SURVEYING WITH STEEL TAPE

Determining the Size of a Given Angle.

Sine Method.—Refer to Fig. 2. Let angle BAC be the angle to be measured. Set the range poles at B and C with the tape measure out from A on line AB some even distance, say 40, 50, 60, 80 or 100 feet. Locate this point as D with a chain pin. Do

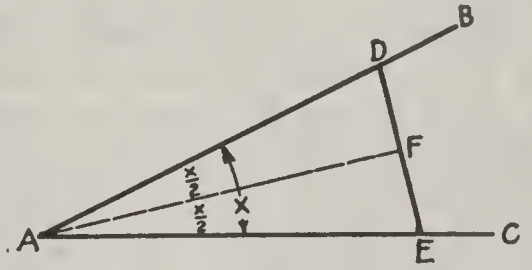

Fig. 2.

the same thing on line AC, using the same distance, and thus locate point E; mark with a chain pin. Now find the exact distance between D and E in feet and tenths of a foot. The size of angle BAC can now be found by the following computations. Take half the distance DE; divide it by the distance AD; look this value up in the table of natural sines and find the angle it represents. Twice this angle will be the angle BAC.

Proof.—AF divides the angle BAC into equal parts and AFD is a right angle. Why? Let the angle BAC be represented by X. Then sine X/2 equals DF over AD. Determine what X/2 is and twice that would be X.

Caution.—Don't multiply sine X/2 by 2 and then look up value of angle and expect to get X.

Large Angles.—Should the angle that is to be measured be greater than 90°, it would be better to measure the angle that is less than 180° or in some cases 360°. In Fig. 3 is shown a case when

instead of measuring the angle BAC it would be better to extend the line AC to some point G and measure the angle GAB. When GAB is found, subtract it from 180° and this will give CAB.

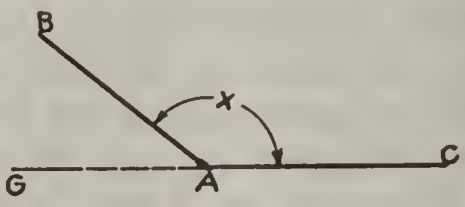

Fig. 3.

Tangent Method.—First Method: Refer to Fig. 4. Let angle CAB be the angle to be measured. Set range poles up at B and C. Measure some even distance, 40, 50, 60 or 100 feet out on line AC from A. Let this point be E. Erect a right angle at E on line AC. Find where the line perpendicular to AC and through E intersects AB and let that point be D. Measure the length of DE. Now, the angle BAC can be found by the following computations. Divide the length of DE by the length AE, and

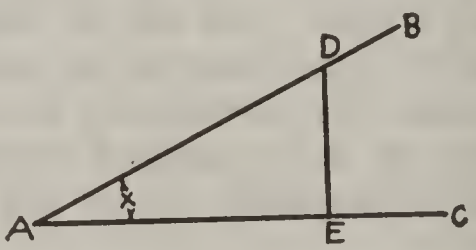

Fig. 4.

with the result find what angle it is the natural tangent of. This angle is BAC.

Proof.—Natural tangent of BAC equals DE over AE.

Second Method.—Refer to Fig. 2. Proceed the same as was done in Sine Method and get the lengths of AE and AD also DE. Then located F on the ground and mark it with a chain pin. Measure AF, getting its length in feet and tenth of a foot. Now, the angle can be obtained by the following computations:

Divide length of DF by the length AF. Find what angle this value is the natural tangent of. Twice this angle will be angle BAC.

Choice of Method.—The first method can be used on small angles, while the second is better for larger angles. When a check is wanted, the second method is best, as the sine method can be also worked for the value obtained.

Large Angles.—The same remarks given under Sine Method, regarding the obtaining of values of angles approaching or greater than 180°, also apply here.

Practical Applications.—The ability to determine the size of an angle in the fence corner of a field by means of a tape will often be found useful in farm life. Then, too, other occasions may arise when it is necessary to determine some angle and no instrument is at hand.

LAYING OFF A GIVEN ANGLE

Right Angles.

Three-Four-Five Method.—Refer to Fig. 5. Let line AB be the line that the right angle is to be laid

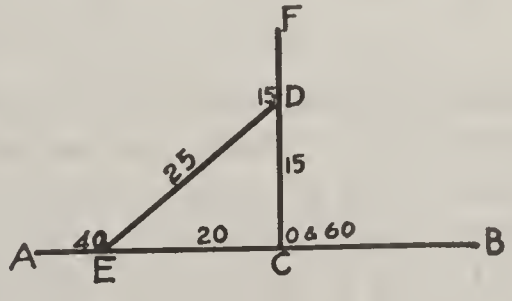

Fig. 5.

off on, and point C to be the point on that line the angle is made. Have one man hold the 0 end of the tape and the 60 foot mark at this point C. Have another man to hold the 40 foot mark on the line

AB. The third man can sight him from point A, so he will be on line. This man at E, then will be 20 feet from C. The third man then takes the 15-foot mark and goes to some point D, which will be found when the tape is pulled tight along line DE and DC. Then a line through CD is perpendicular to AB and the angle ACF is a right angle.

Proof.—20 squared, plus 15 squared, equals 25 squared. This is called the three-four-five method. because any multiples of three, four and five can be used.

Chord Method.

First Method.—Refer to Fig. 6. Let line AB be a straight line and C be the point on that line at which a right angle is wanted. Set up range poles at A and B. Measure off some distance from C and locate any point D on line AB; then measure off the same distance on the other side of C and locate point E on line AB. Using the steel tape, take a

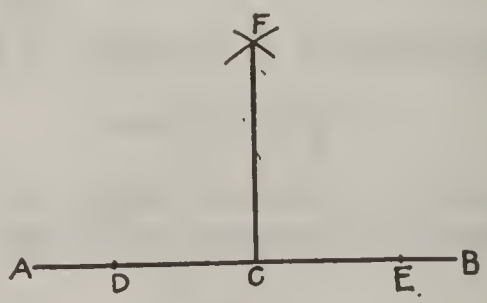

Fig. 6.

radius somewhat greater than EC, and with E as a center describe, with a chain pin, an arc. With the same radius and D as a center, describe another arc. Those two arcs will intersect at some point F. A line through C and F will be perpendicular to AB and ACF, as well as BCF will be right angle. Why?

Second Method.—Refer to Fig. 7. Let AB be a straight line and point C be some point off AB, through which a line perpendicular to AB is wished to be passed. Set up range poles at A and B. With

the steel tape one end at C as a center and a radius greater than CF, describe an arc with a chain pin

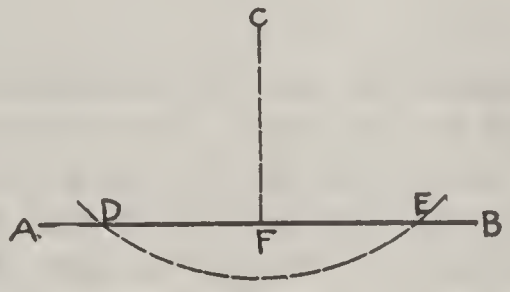

Fig. 7.

which will cut the line AB at two points D and E. A man standing at A can sight along AB and tell when pin intersects this line. Find half the distance between D and E, which will be some point F. A line through F and C will be perpendicular to AB and the angles AFC and BFC will be right angles. Why?

Semicircle Method.—Refer to Fig. 8. Let line AB be a straight line and point C will be some point on that line at which a right angle is to be erected. Set range poles up at A and B. Take some point

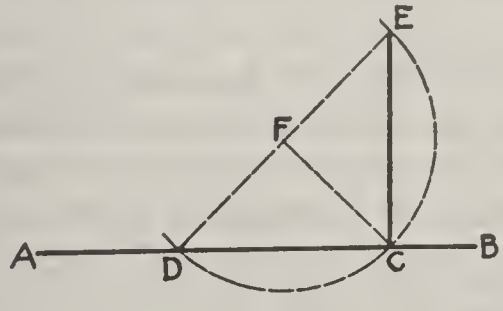

Fig. 8.

F off the line AB. With one end of the steel tape at F and a raidus FC, describe a semicircle which at one end, shall cut AB at some point D. Pass a line through DF until it intersects the semcircle at some point E. A man at D can sight through F, and locate a pin held on the semicircle. Then a line passed through C and E is perpendicular to AB and the angles ACE and BCE are right angles. Why?

ANGLES OTHER THAN A RIGHT ANGLE

Sine Method.—To use this method, do what you did to lay out an angle with Sine Method, only do it backwards. That is, divide the angle you wish to lay out by 2, find the natural sine of that angle. Refer to Fig. 2. Select the lengths AD and AE. Multiply this distance by the sine of the angle and the result will be DF or EF. Twice the distance will be DE. Now, with a pin set at A, the point at which you wish the angle made, measure out on AC or AB, the direction of one of the lines must be given, the distance you selected. Set a pin at this point. Say it is E. Then, with the zero end of the tape at A, and one man holding on the number of feet equal to ADE or AE plus DE, and stationed at E, let another man holding on the number of feet on the tape equal to AD or AE draw the tape so it is tight on E, and on A the point at which he finds himself, will be D. Place a pin here and the given angle is laid out. Prove it.

Tangent Method.—This can be done by working the tangent method of laying out angles backwards. The student should be able to figure this out himself after having studied the method given above.

Practical Applications.—The ability to lay off all kinds of angles with the tape alone will be found very useful, particularly in the case of the right angle, as it can be used at many different times on the farm.

The laying out of a building site is a very frequent necessity on the farm. When it is desired to have the building "square with the world," and nothing near is in that condition, to which the building can be made parallel with, it will be necessary to have an instrument. But under all other conditions, the

site can be easily and quickly laid off with nothing but a tape. Suppose it was wished to lay off a building of the size and shape shown in Fig. 9. Suppose one side, AB was given, and the corner D located; then C could be located by measuring

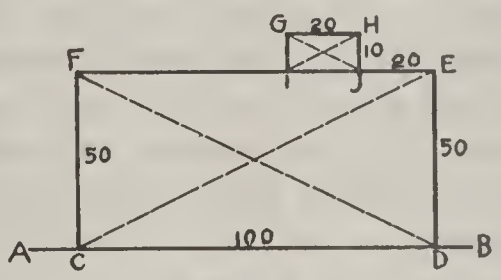

Fig. 9.

100 feet from D on line AB. Next, erect a perpendicular by the 3-4-5 method at the points C. and D. Measure upon these perpendiculars 50 feet and set pins which will locate points E and F. Now, measure the diagonals DF and CE on this rectangle. If they are equal, this part of the building is all right. Then measure on line EF 20 feet from E; this will locate J; 20 feet further along this line will locate I. Erect perpendiculars at I and J and measure up 10 feet on each line, which will locate G and H. Measure the diagonals GJ and IH. If equal, this part of the building is all right. The building is now laid out as all the corners are located. No matter how complicated a building may be, it can be laid out with this method, if it is first divided into square and rectangles.

Parallel Lines.—One line parallel to another can be laid off as mentioned above in laying off a building. They should be checked the same way.

TABLE OF AREAS DRAINED BY TILE

The following table gives the number of acres that different tile will drain with the various grades or falls. To look up the size of tile needed to drain a certain number of acres with a given fall, look up the fall or grade in the left hand column and then move to the right along the horizontal column opposite this grade until the number of acres is found. Then go vertically along this column and the size of tile will be found.

Suppose 36 acres is to be drained with a fall of .2 feet per 100 feet. Come down the left-hand column until .2 is found, then go to the right until 36 is found, and this number 36 is found in the same vertical column, as 10-inch tile. Therefore, a ten-inch tile is to be used.

Areas Drained by Tile Mains Where One-Half of Water is Removed in Twenty-Four Hours.

(Based on Kutter's Formula Where "N" equals .015.)

Fall Per 100 Ft.	Diameter of Tile in Inches									
	4	5	6	7	8	10	12	15	18	24
.05	1	2	4	6	9	17	29	52	87	190
.06	1	2	5	7	10	19	32	57	97	208
.07	1	2	5	7	11	21	35	62	105	226
.08	2	3	5	8	12	23	38	67	112	244
.09	2	3	6	9	13	24	41	72	119	262
.10	2	3	6	9	14	26	43	76	126	280
.12	2	3	6	9	14	27	46	82	137	310
.14	2	3	6	10	16	29	49	89	146	354
.16	2	4	7	11	17	31	53	96	156	358
.18	2	4	7	12	18	33	56	104	166	377
.20	2	5	8	13	20	36	59	108	176	396
.25	2	5	9	14	21	39	66	120	198	440
.30	3	6	10	16	24	44	73	132	216	487
.40	4	7	12	18	28	50	85	155	251	565
.50	4	8	13	21	30	56	95	174	281	628

Fall Per 100 Ft.	Diameter of Tile in Inches								
	4	5	6	7	8	10	12	15	18
.60	5	9	15	23	33	62	104	189	309
.70	5	9	16	25	36	67	112	203	333
.80	5	10	17	27	39	72	120	217	356
.90	6	11	18	28	41	76	127	230	380
1.00	6	11	19	29	43	80	134	244	400
1.25	7	12	21	33	48	90	150	271	
1.50	7	14	24	36	53	98	165		
1.75	8	15	25	39	57	105	172		
2.00	9	16	27	42	61	113	189		
3.00	10	20	33	51	75	139			

TILE DRAINAGE ESTIMATING

Preliminary Estimate of Cost.—It is often necessary to make a preliminary estimate of the cost before any surveying has been done in order to give an approximate cost of the drainage. The following figures given by Elliott will be of assistance in this work.

The number of tile needed for laterals to drain an acre of ground with different spacings:

20	feet	apart,	2178	feet	per	acre.
25	"	"	1742	"	"	"
30	"	"	1452	"	"	"
33	"	"	1320	"	"	"
40	"	"	1089	"	"	"
50	"	"	872	"	"	"
66	"	"	660	"	"	"
80	"	"	545	"	"	"
100	"	"	436	"	"	"
150	"	"	291	"	"	"
200	"	"	218	"	"	"

The number of feet of mains is not included in this table and must be added.

Bill of Materials.—After the survey has been made and the tile lines plotted up on the map, a bill of materials should be made out. This bill should contain the number of feet of each size of tile needed. The actual number of feet needed should be increased 10% in order to allow for breakage. The number of tile specials and materials for accessories should all be included.

Estimating Cost.—The bill of material will serve as a basis for estimating cost of installing the tile drainage. The cost can be divided into five parts: cost of tile, cost of hauling, cost of installing tile, cost of accessories, and cost of engineering and superintendence.

Cost of Tile.—The cost of tile varies with different states and parts of the state. They are quoted in lots of 1,000 feet. The following prices are about the average carload lot prices, delivered at the farmer's railroad station, in Mississippi:

MISSISSIPPI DRAIN TILE PRICE PER 1,000 FEET

4	inch	tile,	$ 16.00	per	1,000	feet.
5	"	"	24.00	"	"	"
6	"	"	30.00	"	"	"
7	"	"	40.00	"	"	"
8	"	"	55.00	"	"	"
10	"	"	75.00	"	"	"
12	"	"	110.00	"	"	"
14	"	"	175.00	"	"	"
16	"	"	220.00	"	"	"
18	"	"	300.00	"	"	"
20	"	"	385.00	"	"	"
22	"	"	460.00	"	"	"
24	"	"	520.00	"	"	"

Cost of Hauling.—The cost of hauling the tile from the railroad station to the farm should be

estimated. In order to determine this, it is necessary to know the weight of various sizes of tile. The following table, given from Elliott's Practical Farm Drainage, will give this information.

WEIGHT OF CLAY DRAIN TILE

Size in Inches	Weight per Ft. in Lbs.	Average Carload in Feet	No. of Feet per Ton
4	6	6500	334
5	8	5000	250
6	11	4000	182
7	14	3000	143
8	18	2400	111
10	25	1600	80
12	33	1000	60
14	43	800	56
16	53	500	38
18	70	400	27
20	83	332	24
22	100	320	20
24	112	300	18

The number of tons of tile to be hauled should be determined and the distance in miles. Then the following table of cost of hauling will enable the total cost to be computed. This table is also taken from Elliott's Practical Farm Drainage.

COST OF HAULING

Hauling, one mile, .	$ .65 per ton.
Hauling, two miles, .	.80 per ton.
Hauling, three miles, .	1.15 per ton.
Hauling, four miles, .	1.35 per ton.
Hauling, five miles, .	1.60 per ton.

This table of cost is with the road in fair condition and allowing the team and driver $3.50 per day.

Cost of Installing Tile.—This cost can be divided into two parts, cost of digging and laying, which

consists of excavating the ditch, laying the tile and placing enough dirt on top of the tile to keep it from moving. Where the farmer does his own work, this is the way it can be figured, or where the ditch is dug by a machine, they usually do not care to take the contract for refilling the ditch. However, where the work is done by some contractors, they will contract for the entire work.

The prices given below are by a tile contractor who has done considerable work near Tupelo, Miss. They are prices for the work complete, digging ditch, laying tile and filling ditch again.

TILE PRICES

Prices for Tile Laying Complete as furnished by Lee Brewster, Baldwyn, Miss., December 18, 1913. Cost in cents per inch of depth for one rod.

	DEPTH IN INCHES		
Size of Tile	48 in. or Less	48 in. to 60 in.	60 in. to 96 in.
4″	1 cents	1¼ cents	
5″	1 "	1¼ "	
6″	1¼ "	1½ "	
8″	1½ "	1¾ "	2 cents
10″	2 "	2¼ "	2½ "
12″	2¼ "	2½ "	2¾ "
15″		3 "	3¼ "
18″		3½ "	4 "

Machine ditching and laying costs about 25 cents per rod for 4 to 6 inch tile laid 3 feet deep. This includes digging, laying and putting in just enough to hold the tile in place.

The cost of filling the ditch is as follows:

Filling ditch 3 ft. deep, by hand, 6 cents per rod.

Filling ditch 3 ft. deep, scraper or plow, 3 cents per rod.

The above is for up to 6 inch tile.

Deeper and wider ditches in proportion.

Cost of Accessories.—The cost of accessories should be figured from the materials and labor needed. The amount of brick, cement, sand, gravel, etc., should all be made out and cost figured at market prices.

Cost of Engineering and Superintendence.—Where the farmer is able to do this himself, it need not be taken into account, but in cases where it is to be taken into account, it usually runs about five per cent of the total cost.

COMPUTING AREAS

Area of a Square.—The area of a square is the square of one of its sides.

Area of Parallelogram.—A parallelogram is a figure with four straight sides, the opposite sides

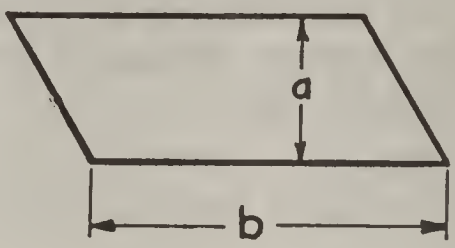

Fig. 10.
Area equal a x b.

of which are parallel. (Fig. 10.) The area of this figure is equal to the base times the altitude.

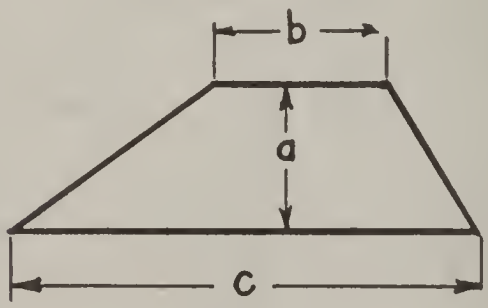

Fig. 11.

$$\text{Area} \frac{b + c}{2} \times a$$

Area of a Trapezoid.—A trapezoid is a figure having four straight sides only two of which are parallel. (Fig. 11.) The area of this figure is equal to the altitude times the mean length of the parallel sides.

Area of a Triangle.—First, base and altitude

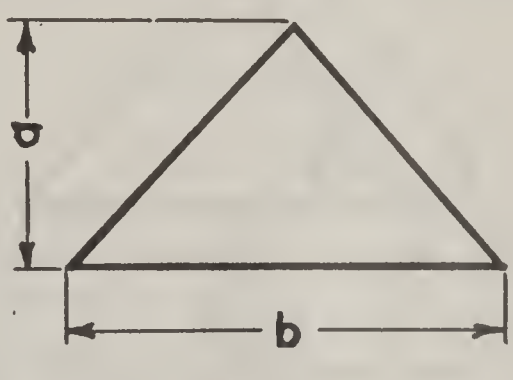

Fig. 12.

$$\text{Area} \frac{a \times b}{2}$$

given. The area of a triangle is equal to one-half the base times the altitude. (Fig. 12.)

Second, three sides given. Let the sum of the sides of a triangle be equal to two times s, then apply the formula given in Fig. 13.

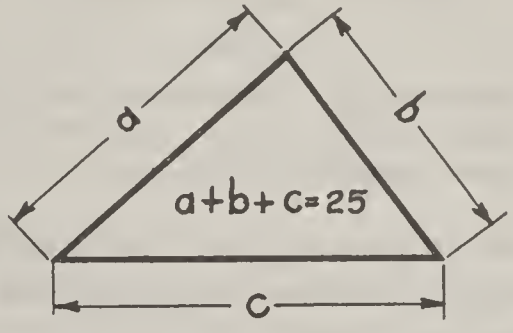

Fig. 13.

$$\text{Area equals } \sqrt{s\ (s-a)\ (s-b)\ (s-c)}$$

a —|— b —|—c equal 2s

Third, two sides and the included angle given. The area of a triangle is equal to one-half the product obtained by multiplying the two sides together and then multiplying the result by the sine of the included angle. (Fig. 14.)

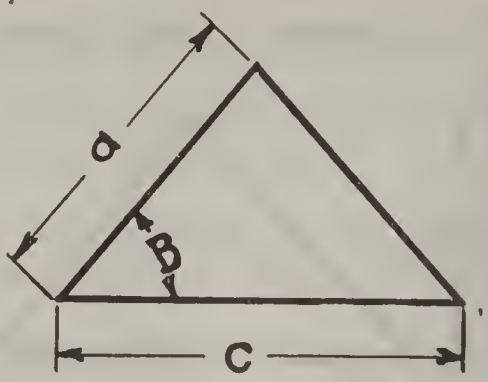

Fig. 14.
Area equal ½a x c x sine B.

Area of a Trapezium.—A trapezium is a figure having four straight lines, no two sizes of which are parallel. Divide the trapezium into two triangles and determine the area of each triangle, then add

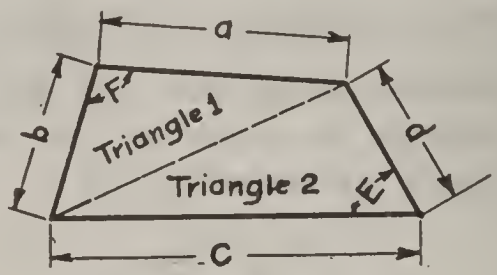

Fig. 15.
Area triangle 1 equals ½ab sine F.
Area triangle 2 equals ½cd sine E.
Area trapezium equals area 1–|–2.

the two areas together. In Fig. 15 this is shown when the length of four sides and the size of two of the angles are given.

Area of a Many-Sided Figure.—In obtaining the area of a many-sided figure it is best, if possible, to resolve it into a number of triangles and then measure the sides of the triangles.

TABLES OF MEASUREMENT

Linear Measure

(United States.)

12 inches equal 1 foot.
3 feet equal 1 yard.
16½ feet equal 1 rod.
320 rods equal one mile.
5280 feet equal one mile.
1760 yards equal 1 mile.

Metric.

10 millimeters equal 1 centimeter.
10 centimeters equal 1 decimeter.
10 decimeters equal 1 meter.
1000 meters equal 1 kilometer.

Gunters Chain.

1 chain equals 100 links.
1 chain equals 4 rods.
80 chains equal 1 mile.

Conversion Table

1 chain equals 66 feet.
1 chain equals 20.1168 meters.
1 link equals 7.92 inches.
1 link equals 0.66 feet.
1 foot equals 0.3048 meters.
1 inch equals 2.54 centimeters.
1 meter equals 3.28023 feet.
1 centimeter equals .3937 inches.

Conversion Table

To Change Tenths and Hundredths of a Foot to Inches.

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
0	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	0
.1	1 1/4	1 3/8	1 1/2	1 5/8	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	.1
.2	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/8	3 1/4	3 3/8	3 1/2	.2
.3	3 5/8	3 3/4	3 7/8	4	4 1/8	4 1/4	4 3/8	4 1/2	4 5/8	4 3/4	.3
.4	4 7/8	5	5	5 1/8	5 1/4	5 3/8	5 1/2	5 5/8	5 3/4	5 7/8	.4
.5	6	6 1/8	6 1/4	6 3/8	6 1/2	6 5/8	6 3/4	6 7/8	7	7 1/8	.5
.6	7 1/4	7 3/8	7 1/2	7 5/8	7 5/8	7 3/4	7 7/8	8	8 1/8	8 1/4	.6
.7	8 3/8	8 1/2	8 5/8	8 3/4	8 7/8	9	9 1/8	9 1/4	9 3/8	9 1/2	.7
.8	9 5/8	9 3/4	9 7/8	10	10 1/8	10 1/4	10 3/8	10 1/2	10 3/8	10 3/4	.8
.9	10 7/8	11	11	11 1/8	11 1/4	11 3/8	11 1/2	11 3/8	11 3/4	11 7/8	.9

Surface Measure.

United States.

144 sq. in equal 1 sq. ft.
9 sq. ft. equals 1 sq. yd.
30¼ sq. yd. equal 1 sq. rd.
272¼ sq. ft. or 43560 sq ft. or 160 sq. rods equal 1 acre.

Metric

100 sq. millimeters equal 1 sq. cen.
1000 sq. centimeters equal 1 sq. decim.
1 sq. meter equals 10.7639 sq. feet.
10000 sq. metors equals 1 hectaro.

Conversion Table

10 sq. chains equals 1 acre.
1 acre equals 4046.87 sq. meters.
1 sq. meter equals 10.7369 sq. feet.
1 hectare equals 2.47104 acres.

LOGARITHMS OF NUMBERS

FROM 0 TO 1000

No.	0	1	2	3	4	5	6	7	8	9
0	0	00000	30103	47712	60206	69897	77815	84510	90309	95424
10	00000	00432	00860	01284	01703	02119	02531	02938	03342	03743
11	04139	04532	04922	05308	05690	06070	06446	06819	07188	07555
12	07918	08279	08636	08991	09342	09691	10037	10380	10721	11059
13	11394	11727	12057	12385	12710	13033	13354	13672	13988	14301
14	14613	14922	15229	15534	15836	16137	16435	16732	17026	17319
15	17609	17898	18184	18469	18752	19033	19312	19590	19866	20140
16	20412	20683	20952	21219	21484	21748	22011	22272	22531	22789
17	23045	23300	23553	23805	24055	24304	24551	24797	25042	25285
18	25527	25768	26007	26245	26482	26717	26951	27184	27416	27646
19	27875	28103	28330	28556	28780	29003	29226	29447	29667	29885
20	30103	30320	30535	30750	30963	31175	31387	31597	31806	32015
21	32222	32428	32634	32838	33041	33244	33445	33646	33846	34044
22	34242	34439	34635	34830	35025	35218	35411	35603	35793	35984
23	36173	36361	36549	36736	36922	37107	37291	37475	37658	37840
24	38021	38202	38382	38561	38739	38917	39094	39270	39445	39620
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330
26	41497	41664	41830	41996	42160	42325	42488	42651	42813	42975
27	43136	43297	43457	43616	43775	43933	44091	44248	44404	44560
28	44716	44871	45025	45179	45332	45484	45637	45788	45939	46090
29	46240	46389	46538	46687	46835	46982	47129	47276	47422	47567
30	47712	47857	48001	48144	48287	48430	48572	48714	48855	48996
31	49136	49276	49415	49554	49693	49831	49969	50106	50243	50379
32	50515	50651	50786	50920	51055	51188	51322	51455	51587	51720
33	51851	51983	52114	52244	52375	52504	52633	52763	52892	53020
34	53148	53275	53403	53529	53656	53782	53908	54033	54158	54283
35	54407	54531	54654	54777	54900	55023	55145	55267	55388	55509
36	55630	55751	55871	55991	56110	56229	56348	56467	56585	56703
37	56820	56937	57054	57171	57287	57403	57519	57634	57749	57864
38	57978	58093	58206	58320	58433	58546	58659	58771	58883	58995
39	59106	59218	59329	59439	59550	59660	59770	59879	59988	60097
40	60206	60314	60423	60531	60638	60746	60853	60959	61066	61172
41	61278	61384	61490	61595	61700	61805	61909	62014	62118	62221
42	62325	62428	62531	62634	62737	62839	62941	63043	63144	63246
43	63347	63448	63548	63649	63749	63849	63949	64048	64147	64246
44	64345	64444	64542	64640	64738	64836	64933	65031	65128	65225

LOGARITHMS OF NUMBERS, FROM 0 TO 1000.

(Continued.)

No.	0	1	2	3	4	5	6	7	8	9
45	65321	65418	65514	65610	65706	65801	65896	65992	66087	66181
46	66276	66370	66464	66558	66652	66745	66839	66932	67025	67117
47	67210	67302	67394	67486	67578	67669	67761	67852	67943	68034
48	68124	68215	68305	68395	68485	68574	68664	68753	68842	68931
49	69020	69108	69197	69285	69373	69461	69548	69636	69723	69810
50	69897	69984	70070	70157	70243	70329	70415	70501	70586	70672
51	70757	70842	70927	71012	71096	71181	71265	71349	71433	71517
52	71600	71684	71767	71850	71933	72016	72099	72181	72263	72346
53	72428	72509	72591	72673	72754	72835	72916	72997	73078	73159
54	73239	73320	73400	73480	73560	73640	73719	73799	73878	73957
55	74036	74115	74194	74273	74351	74429	74507	74586	74663	74741
56	74819	74896	74974	75051	75128	75205	75282	75358	75435	75511
57	75587	75664	75740	75815	75891	75967	76042	76118	76193	76268
58	76343	76418	76492	76567	76641	76716	76790	76864	76938	77012
59	77085	77159	77232	77305	77379	77452	77525	77597	77670	77743
60	77815	77887	77960	78032	78104	78176	78247	78319	78390	78462
61	78533	78604	78675	78746	78817	78888	78958	79029	79099	79169
62	79239	79309	79379	79449	79518	79588	79657	79727	79796	79865
63	79934	80003	80072	80140	80209	80277	80346	80414	80482	80550
64	80618	80686	80754	80821	80889	80956	81023	81090	81158	81224
65	81291	81358	81425	81491	81558	81624	81690	81756	81823	81889
66	81954	82020	82086	82151	82217	82282	82347	82413	82478	82543
67	82607	82672	82737	82802	82866	82930	82995	83059	83123	83187
68	83251	83315	83378	83442	83506	83569	83632	83696	83759	83822
69	83885	83948	84011	84073	84136	84198	84261	84323	84386	84448
70	84510	84572	84634	84696	84757	84819	84880	84942	85003	85065
71	85126	85187	85248	85309	85370	85431	85491	85552	85612	85673
72	85733	85794	85854	85914	85974	86034	86094	86153	86213	86273
73	86332	86392	86451	86510	86570	86629	86688	86747	86806	86864
74	86923	86982	87040	87099	87157	87216	87274	87332	87390	87448
75	87506	87564	87622	87680	87737	87795	87852	87910	87967	88024
76	88081	88138	88196	88252	88309	88366	88423	88480	88536	88593
77	88649	88705	88762	88818	88874	88930	88986	89042	89098	89154
78	89209	89265	89321	89376	89432	89487	89542	89597	89653	89708
79	89763	89818	89873	89927	89982	90037	90091	90146	90200	90255

LOGARITHMS OF NUMBERS, FROM 0 TO 1000.

(Continued.)

No.	0	1	2	3	4	5	6	7	8	9
80	90309	90363	90417	90472	90526	90580	90634	90687	90741	90795
81	90849	90902	90956	91009	91062	91116	91169	91222	91275	91328
82	91381	91434	91487	91540	91593	91645	91698	91751	91803	91855
83	91908	91960	92012	92065	92117	92169	92221	92273	92324	92376
84	92428	92480	92531	92583	92634	92686	92737	92788	92840	92891
85	92942	92993	93044	93095	93146	93197	93247	93298	93349	93399
86	93450	93500	93551	93601	93651	93702	93752	93802	93852	93902
87	93952	94002	94052	94101	94151	94201	94250	94300	94349	94399
88	94448	94498	94547	94596	94645	94694	94743	94792	94841	94890
89	94939	94988	95036	95085	95134	95182	95231	95279	95328	95376
90	95424	95472	95521	95569	95617	95665	95713	95761	95809	95856
91	95904	95952	95999	96047	96095	96142	96190	96237	96284	96332
92	96379	96426	96473	96520	96567	96614	96661	96708	96755	96802
93	96848	96895	96942	96988	97035	97081	97128	97174	97220	97267
94	97313	97359	97405	97451	97497	97543	97589	97635	97681	97727
95	97772	97818	97864	97909	97955	98000	98046	98091	98137	98182
96	98227	98272	98318	98363	98408	98453	98498	98543	98588	98632
97	98677	98722	98767	98811	98856	98900	98945	98989	99034	99078
98	99123	99167	99211	99255	99300	99344	99388	99432	99476	99520
99	99564	99607	99651	99695	99739	99782	99826	99870	99913	99957

NATURAL SINES

Deg.	0′	10′	20′	30′	40′	50′	Deg.
0	.0000	.0029	.0058	.0087	.0116	.0145	89
1	.0175	.0204	.0233	.0262	.0291	.0320	88
2	.0349	.0378	.0407	.0436	.0465	.0494	87
3	.0523	.0552	.0581	.0610	.0640	.0669	86
4	.0698	.0727	.0756	.0785	.0814	.0843	85
5	.0872	.0901	.0929	.0958	.0987	.1016	84
6	.1045	.1074	.1103	.1132	.1161	.1190	83
7	.1219	.1248	.1279	.1305	.1334	.1363	82
8	.1392	.1421	.1449	.1478	.1507	.1536	81
9	.1564	.1593	.1622	.1650	.1679	.1708	80
10	.1736	.1765	.1794	.1822	.1851	.1880	79
11	.1908	.1937	.1965	.1994	.2022	.2051	78
12	.2079	.2108	.2136	.2164	.2193	.2221	77
13	.2250	.2278	.2306	.2334	.2363	.2391	76
14	.2419	.2447	.2476	.2504	.2532	.2560	75
15	.2588	.2616	.2644	.2672	.2700	.2728	74
16	.2756	.2784	.2812	.2840	.2868	.2890	73
17	.2924	.2952	.2979	.3007	.3035	.3062	72
18	.3090	.3118	.3145	.3173	.3201	.3228	71
19	.3256	.3283	.3311	.3338	.3365	.3393	70
20	.3420	.3448	.3475	.3502	.3529	.3557	69
21	.3584	.3611	.3638	.3665	.3692	.3719	68
22	.3746	.3773	.3800	.3827	.3854	.3881	67
23	.3907	.3934	.3961	.3987	,4014	.4041	66
24	.4067	.4094	.4120	.4147	.4173	.4200	65
25	.4226	.4253	.4279	.4305	.4331	.4358	64
26	.4384	.4410	.4436	.4462	.4488	.4514	63
27	.4540	.4566	.4592	.4617	.4643	.4669	62
28	.4695	.4720	.4746	.4772	.4797	.4823	61
29	.4848	.4874	.4899	.4924	.4950	.4975	60
30	.5000	.5025	.5050	.5075	.5100	.5125	59
31	.5150	.5175	.5200	.5225	.5250	.5275	58
Deg.	60′	50′	40′	30′	20′	10′	Deg.

NATURAL COSINES

NATURAL SINES

(Continued.)

Deg.	0′	10′	20′	30′	40′	50′	Deg.
32	.5299	.5324	.5348	.5373	.5398	.5422	57
33	.5446	.5471	.5495	.5519	.5544	.5568	56
34	.5592	.5616	.5640	.5664	.5688	.5712	55
35	.5736	.5760	.5783	.5807	.5831	.5854	54
36	.5878	.5901	.5925	.5948	.5972	.5995	53
37	.6018	.6041	.6065	.6088	.6111	.6134	52
38	.6157	.6180	.6202	.6225	.6248	.6271	51
39	.6293	.6316	.6338	.6361	.6383	.6406	50
40	.6428	.6450	.6472	.6494	.6517	.6539	49
41	.6561	.6583	.6604	.6626	.6648	.6670	48
42	.6691	.6713	.6734	.6756	.6777	6799	47
43	.6820	.6841	.6862	.6884	.6905	.6926	46
44	.6947	.6967	.6988	.7009	.7030	.7050	45
45	.7071	.7092	.7112	.7133	.7153	.7173	44
46	.7193	.7214	.7234	.7254	.7274	.7294	43
47	.7314	.7333	.7353	.7373	.7392	.7412	42
48	.7431	.7451	.7470	.7490	.7509	.7528	41
49	.7547	.7566	.7585	.7604	.7623	.7642	40
50	.7660	.7679	.7698	.7716	.7735	.7753	39
51	.7771	.7790	.7808	.7826	.7844	.7862	38
52	.7880	.7898	.7916	.7934	.7951	.7969	37
53	.7986	.8004	.8021	.8039	.8056	.8073	36
54	.8090	.8107	.8124	.8141	.8158	.8175	35
55	.8192	.8208	.8225	.8241	.8258	.8274	34
56	.8290	.8307	.8323	.8339	.8355	.8371	33
57	.8387	.8403	.8418	.8434	.8450	.8465	32
58	.8480	.8496	.8511	.8526	.8542	.8557	31
59	.8572	.8587	.8601	.8616	.8631	.8646	30
60	.8660	.8675	.8689	.8704	.8718	.8732	29
61	.8746	.8760	.8774	.8788	.8802	.8816	28
Deg.	60′	50′	40′	30′	20′	10′	Deg.

NATURAL COSINES

NATURAL SINES

(Continued.)

Deg.	0′	10′	20′	30′	40′	50′	Deg.
62	.8829	.8843	.8857	.8870	.8884	.8897	27
63	.8910	.8923	.8936	.8949	.8962	.8975	26
64	.8988	.9001	.9013	.9026	.9038	.9051	25
65	.9063	.9075	.9088	.9100	.9112	.9124	24
66	.9135	.9147	.9159	.9171	.9182	.9194	23
67	.9205	.9216	.9228	.9239	.9250	.9261	22
68	.9272	.9283	.9293	.9304	.9315	.9325	21
69	.9336	.9346	.9356	.9367	.9377	.9387	20
70	.9397	.9407	.9417	.9426	.9436	.9446	19
71	.9455	.9465	.9474	.9483	.9492	.9502	18
72	.9511	.9520	.9528	.9537	.9546	.9555	17
73	.9563	.9572	.9580	.9588	.9596	.9605	16
74	.9613	.9621	.9628	.9636	.9644	.9652	15
75	.9659	.9667	.9674	.9681	.9689	.9696	14
76	.9703	.9710	.9717	.9724	.9730	.9737	13
77	.9744	.9750	.9757	.9763	.9769	.9775	12
78	.9781	.9787	.9793	.9799	.9805	.9811	11
79	.9816	.9822	.9827	.9833	.9838	.9843	10
80	.9848	.9853	.9858	.9863	.9868	.9872	9
81	.9877	.9881	.9886	.9890	.9894	.9899	8
82	.9903	.9907	.9911	.9914	.9918	.9922	7
83	.9925	.9929	.9932	.9936	.9939	.9942	6
84	.9945	.9948	.9951	.9954	.9957	.9959	5
85	.9962	.9964	.9967	.9969	.9971	.9974	4
86	.9976	.9978	.9980	.9981	.9983	.9985	3
87	.9986	.9988	.9989	.9990	.9992	.9993	2
88	.9994	.9995	.9996	.9997	.9997	.9998	1
89	.9989	.9999	.9999	.9999	1.0000	1.0000	0
Deg.	60′	50′	40′	30′	20′	10′	Deg.

NATURAL COSINES

NATURAL TANGENTS

Deg.	0′	10′	20′	30′	40′	50′	Deg.
0	.0000	.0029	.0058	.0087	.0116	.0145	89
1	.0175	.0204	.0233	.0262	.0291	.0320	88
2	.0349	.0378	.0407	.0437	.0466	.0495	87
3	.0524	.0553	.0582	.0612	.0641	.0670	86
4	.0699	.0729	.0758	.0787	.0816	.0846	85
5	.0875	.0904	.0934	.0963	.0992	.1022	84
6	.1051	.1080	.1110	.1139	.1169	.1198	83
7	.1228	.1257	.1287	.1317	.1346	.1376	82
8	.1405	.1435	.1465	.1495	.1524	.1554	81
9	.1584	.1614	.1644	.1673	.1703	.1733	80
10	.1763	.1793	.1823	.1853	.1883	.1914	79
11	.1944	.1974	.2004	.2035	.2065	.2095	78
12	.2126	.2156	.2186	.2217	.2247	.2278	77
13	.2309	.2339	.2370	.2401	.2432	.2462	76
14	.2493	.2524	.2555	.2586	.2617	.2648	75
15	.2679	.2711	.2742	.2773	.2805	.2836	74
16	.2867	.2899	.2931	.2962	.2994	.3026	73
17	.3057	.3089	.3121	.3153	.3185	.3217	72
18	.3249	.3281	.3314	.3346	.3378	.3411	71
19	.3443	.3476	.3508	.3541	.3574	.3607	70
20	.3640	.3673	.3706	.3739	.3772	.3805	69
21	.3839	.3872	.3906	.3939	.3973	.4006	68
22	.4040	.4074	.4108	.4142	.4176	.4210	67
23	.4245	.4279	.4314	.4348	.4383	.4417	66
24	.4452	.4487	.4522	.4557	.4592	.4628	65
25	.4663	.4699	.4734	.4770	.4806	.4841	64
26	.4877	.4913	.4950	.4986	.5022	.5059	63
27	.5095	.5132	.5169	.5206	.5243	.5280	62
28	.5317	.5354	.5392	.5430	.5467	.5505	61
29	.5543	.5581	.5619	.5658	.5696	.5735	60
30	.5774	.5812	.5851	.5890	.5930	.5969	59
31	.6009	.6048	.6088	.6128	.6168	.6208	58
Deg.	60′	50′	40′	30′	20′	10′	Deg.

NATURAL COTANGENTS

NATURAL TANGENTS

(Continued.)

Deg.	0′	10′	20′	30′	40′	50′	Deg.
32	.6249	.6289	.6330	.6371	.6412	.6453	57
33	.6494	.6536	.6577	.6619	.6661	.6703	56
34	.6745	.6787	.6830	.6873	.6916	.6959	55
35	.7002	.7040	.7089	.7133	.7177	.7221	54
36	.7265	.7310	.7355	.7400	.7445	.7490	53
37	.7536	.7581	.7627	.7673	.7720	.7766	52
38	.7813	.7860	.7907	.7954	.8002	.8050	51
39	.8098	.8146	.8195	.8243	.8292	.8342	50
40	.8391	.8441	.8491	.8541	.8591	.8642	49
41	.8693	.8744	.8796	.8847	.8899	.8952	48
42	.9004	.9057	.9110	.9163	.9217	.9271	47
43	.9325	.9380	.9435	.9490	.9545	.9601	46
44	.9657	.9713	.9770	.9827	.9884	.9942	45
45	1.0000	1.0058	1.0117	1.0176	1.0235	1.0295	44
46	1.0355	1.0416	1.0477	1.0533	1.0599	1.0661	43
47	1.0724	1.0786	1.0850	1.0913	.10977	1.1041	42
48	1.1106	1.1171	1.1237	1.1303	1.1369	1.1436	41
49	1.1504	1.1571	1.1640	1.1708	1.1778	1.1847	40
50	1.1918	1.1988	1.2059	1.2131	1.2203	1.2276	39
51	1.2349	1.2423	1.2497	1.2572	1.2647	1.2723	38
52	1.2799	1.2876	1.2954	1.3032	1.3111	1.3190	37
53	1.3270	1.3351	1.3452	1.3514	1.3597	1.3680	36
54	1.3764	1.3848	1.3934	1,4019	1.4106	1.4193	35
55	1.4281	1,4370	1.4460	1,4550	1,4641	1,4733	34
56	1.4826	1.4919	1.5013	1.5108	1.5204	1.5301	33
57	1.5399	1.5497	1.5597	1.5697	1.5798	1.5900	32
58	1.6003	1.6107	1.6212	1.6319	1.6426	1.6534	31
59	1.6643	1.6753	1.6864	1.6977	1.7090	1.7205	30
60	1.7321	1.7437	1.7556	1.7675	1.7797	1.7917	29
61	1.8040	1.8165	1.8291	1.8418	1.8546	1.8676	28
Deg.	60′	50′	40′	30′	20′	10′	Deg.

NATURAL COTANGENTS

NATURAL TANGENTS

(Continued.)

Deg.	0′	10′	20′	30′	40′	50′	Deg.
62	1.8807	1.8940	1.9074	1.9210	1.9347	1.9486	27
63	1.9626	1.9768	1.9912	2.0057	2.0204	2.0353	26
64	2.0503	2.0655	2.0809	2.0965	2.1123	2.1283	25
65	2.1445	2.1609	2.1775	2.1943	2.2113	2.2286	24
66	2.2460	2.2637	2.2817	2.2998	2.3183	2.3369	23
67	2.3559	2.3750	2.3945	2.4142	2.4342	2.4545	22
68	2.4751	2.4960	2.5172	2.5386	2.5605	2.5826	21
69	2.6051	2.6279	2.6511	2.6746	2.6985	2.7228	20
70	2.7475	2.7725	2.7980	2.8239	2.8502	2.8770	19
71	2.9042	2.9319	2.9600	2.9887	3.0178	3.0475	18
72	3.0777	3.1084	3.1397	3.1716	3.2041	3.2371	17
73	3.2709	3.3052	3.3402	3.3759	3.4124	3.4495	16
74	3.4874	3.5261	3.5656	3.6059	3.6470	3.6891	15
75	3.7321	3.7760	3.8208	3.8657	3.9136	3.9617	14
76	4.0108	4.0611	4.1126	4.1653	4.2193	4.2747	13
77	4.3315	4.3897	4.4494	4.5107	4.5736	4.6382	12
78	4.7046	4.7729	4.8430	4.9152	4.9894	5.0658	11
79	5.1446	5.2257	5.3093	5.3955	5.4845	5.5764	10
80	5.6713	5.7694	5.8708	5.9758	6.0844	6.1970	9
81	6.3138	6.4348	6.5606	6.6912	6.8269	6.9682	8
82	7.1154	7.2687	7.4287	7.5958	7.7704	7.9530	7
83	8.1443	8.3450	8.5555	8.7769	9.0098	9.2553	6
84	9.5144	9.7882	10.078	10.385	10.711	11.059	5
85	11.430	11.826	12.250	12.706	13.197	13.727	4
86	14.300	14.924	15.605	16.350	17.169	18.075	3
87	19.081	20.206	21.470	22.903	24.542	26.432	2
88	28.636	31.242	34.368	38.189	42.964	49.104	1
89	57.290	68.750	85.940	114.588	171.885	343.77	0
Deg.	60′	50′	40′	30′	20′	10′	Deg.

NATURAL COTANGENTS